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# QUALITY CONCERN IN RICE DECREASED PRICE VALUE

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## Abstract

Quality testing is primarily a matter of determining whether a commodity meets with the specific requirements of cleanliness and purity and is suitable for a particular use. Physical quality of 400 samples of rough and milled rice was evaluated by taking into account eight different parameters as set by a government agency. More than 40% samples exhibited milling degree below 90%. Under milled grains, fraction was beyond acceptable range in 24% samples. 18% of the samples were found marginal regarding moisture contents. Shrunken and shrivelled grains' fraction was present beyond acceptable limit in the all samples. 24% of the samples had broken grains fraction in the marginal range and 18% of the samples were beyond acceptable limit. Regarding the chalk element, 48% of the samples had chalky grains fraction within range but 7% of the samples were marginal and 12% were beyond acceptable limit. Damaged grains were present in 81% of the samples beyond the acceptable range. Overall, 65% of the samples had accurate quality but 35% of the samples were below from the standard criteria. Following specifications of national standards, the rough rice quality was also not satisfactory, particularly, for samples produced through wheat combine machine harvesting.

**Keywords:** Broken, Chalkiness, Milling degree, Physical indicators.

## Introduction

Rice is the nation's second staple food and probably 5000-6000 rice processing units are installed in the country, accounting for 6.7% in value added in agriculture and 1.6% in national gross development and more than three million family's livelihood is attached with the crop economy (Pak Economic Survey, 2011); English papers economic reviews. Value of globally traded rice's 6.3% of total produced rice of the world over is US$8.6 billion. 74% of this trade is on account of developing countries and Pakistan counts about 10% of 6.3%, standing always among top five voluminous exporters (Malhi, 2012a; Samarendu, 2010; Nelson, 2010; Anonymous, 2008; Mohammad and Laurent, 2004). Further, EU market is always considered rich for exporters from all over the world due to good price, stability, easy cash recovery and predictable supply (Dawe, 2010). Over last 13 years, average volume has been 1300MT with maximum 1568MT during the year 2007 (Malhi, 2012a). The demands because rice is consumed as intact kernels and as wholegrain (brown or raw) and because rice is an ingredient in a multitude of foods prepared in homes and by food processing companies across the globe. Rice provides 20% of the world's kilocalorie supply and 15% of human's protein consumption. In some regions of Asia, up to 71% of the daily energy and 70% of the protein intake comes from edible rice. However, both consumer and producer welfare is augmented with improved quality in the competitive market at a lower price and enhanced quality ensures the commodity's credibility. Consequently, benefits from increased demand helps to expand market or capture higher premium (Unnevehr et al., 1992).

Few years ago, Pakistan superseded USA after Vietnam as the world's third largest rice exporter (Anonymous, 2008). Its export volume annual growth average was 25% during previous decade (even 57% during the marketing year 2009–10) but its price value declined by 30% on non-basmati (IRRI-type, coarse varieties) and 33% on basmati of fine quality. This happened because of a loss of the EU market due to aflatoxin detection in basmati rice (Table 2). In a similar

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fashion, another threat looms from USFDA in its preliminary analysis of 200 samples of rice and rice products hailing from different origins, including 34 Indian samples. The authority has found arsenic contents in about 31 samples, including 30 from Indian proportion. The FDA is examining the issue thoroughly (1,200 samples) and will issue recommendations after compilation of results by the end of 2012 (GOP–M/o Food Security Letter No. F.1-14/2012-FSC-II dated January 1st 2013). In the light of initial information, out of 34 samples, 31 contained inorganic arsenic contents in the range of 1.8 to 6.5 microgram per serving (Malhi, 2012b).

**Table I. NAPHIS Pakistan Report based on EU database**

| S.# | Importing country | Confiscated Export | Confiscation Reasons | Confiscation/Notification date |
|---|---|---|---|---|
| 1 | Greece | Rice | Aflatoxins | 27.9.2006 |
| 2 | Netherlands | Rice | Aflatoxins | 28.02.2007 |
| 3 | Italy | Basmati rice | Aflatoxin | 7.6.2007 |
| 4 | UK | Rice | Aflatoxin | 2007. BSR; 16−07−2007 |
| 5 | Italy | Basmati rice | Aflatoxin | 2.08.2007.BVU |
| 6 | Italy | Basmati rice | Aflatoxin | 2007.CJK; 15−10.−2007 |
| 7 | Greece | Super basmati rice | Aflatoxin | 2007.CPA; 14-11-2007 |
| 8 | UK | Rice | Aflatoxins | 07.12.2007 |
| 9 | Sweden | Basmati rice | Aflatoxin | 2007-0953; 2007-0953-Addo1, 3-12-2008, 20-12-2007;2006-07 |
| 10 | Poland | Long grain rice | Aflatoxin | 2008.ACU; 17-01-2008 |
| 11 | Poland | Long grain rice | Aflatoxin | 2008.ADH; 18-01-2008 |
| 12 | UK | Basmati rice/chopped pulverized Curry mix | Aflatoxin | 19-02-2008/ 2008.AIB |
| 13 | Blaize-Lithuania | Long grain white rice | Aflatoxin | 2008.AKA; 3-03-2008 |
| 14 | Greece | Brown rice | Aflatoxin | 27-03-2008 |
| 15 | Lithuania | Long grain white rice | Aflatoxin | AJZ 03-03-2008 |
| 16 | Lithuania | Long grain white rice | Aflatoxin | AJX 3-3-2008 |
| 17 | Greece | Brown rice | Aflatoxin | 2008. ALH; 13-03-2008 |
| 18 | Lithuania | Long grain white rice | Aflatoxin | AJY 03-03-2008 |
| 19 | Lithuania | Long grain white rice | Aflatoxin | 2008.AMH; 18-03-2008 |
| 20 | Lithuania | Long grain white rice | Aflatoxin | AMI, 18-03-2008 |
| 21 | Lithuania | Long grain white rice | Aflatoxin | AMJ, 18-03-2008 |
| 22 | Lithuania | Long grain white rice | Aflatoxin | 2008.AMC; 18-03-2008 |
| 23 | Lithuania | Long grain white rice | Aflatoxin | 2008.AMB; 18-03-2008 |
| 24 | Lithuania | Long grain white rice | Aflatoxin | 2008.AMD; 18-03-2008 |
| 25 | Lithuania | Long grain white rice | Aflatoxin | 2008. AME; 18-03-2008 |
| 26 | Lithuania | Long grain white rice | Aflatoxin | 2008.AMF; 18-03-2008 |
| 27 | Lithuania | Long grain white rice | Aflatoxin | 2008. AMG; 18-03-2008 |
| 28 | UK/EU | Basmati rice | Aflatoxin | AUV-29-05-2008 |
| 29 | Spain | Rice | aflatoxin high level | 2008 BNH; 29-09-2008 |
| 30 | UK/EU | Rice | aflatoxin high level | 2009 ACD/ 28-01-2009 |
| 31 | UK/EU | Broken rice | Aflatoxin | 2009 AKY/ 24-03-2009 |
| 32 | Sweden | Basmati rice | Aflatoxin | 2009.0953; 03rd Aug, 2009 |
| 33 | UK | Rice | total aflatoxin14ppb $B_1$=12− basmati rice | 27-11-2009; 2009.1650 |
| 34 | Greece | Rice | Aflatoxin | 12-03-2010; 2010.ALO |
| 35 | Italy | Rice | Aflatoxin | 9-4-2010; 2010.AQS |
| 36 | UK | Rice | Aflatoxin | 12-4-2010; 2010. 0456 |
| 37 | Germany | Rice | Aflatoxin | 2010.0879; 2-07-2010 |
| 38. | UK | Rice | Aflatoxin | 8-07-2010; 2010.BEP |
| 39 | Greece | Rice | Aflatoxin | 2010.BEJ; 5-8-2010 |
| 40 | Greece | Basmati rice | Aflatoxin | 29-09-2010; 2010.BQY |
| 41 | Germany | Rice | Aflatoxin | 2010.BSU; 13-10-2010 |
| 42 | UK | Rice | Aflatoxin | 2010.BTG; 18-10-2010 |
| 43 | UK | Super basmati rice | Aflatoxin | 2010.CCR; 24-11-2010 |
| 44 | UK | Super basmati rice | Aflatoxin | 2010.CFI; 10-12-2010 |
| 45 | UK | Basmati rice | Aflatoxin | 23-2-2011; 2011.AKZ |

**Table 2. Last seven years approximate export status of milled rice.**

| Parameter Description | Marketing Years (June, May – July) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Basmati -The Fine quality rice varieties status | | | | | | |
| | 2006–07 | 2007–08 | 2008–09 | 2009–10 | 2010–11 | 2011-12 | 2012-13 |
| Volume (in million tonnes) | 0.955 | 0.850, 638 | 0.924, 358 | 1,050052 | 1, 137,943 | 0.975,55 | 0.725 |
| AVG Unit Price in US$ | 556.320$^{m}$ | 971 | 1102 | 825 | 837 | 483$^{m}$ | 423$^{m}$ |
| Average price per MT(US$) | 1584.74 | 1500 | 1300 | 1102 | 825 | 844 | 1100-1200 |
| Annual growth in export | On average 25 % | | | 35 % | 17 % | RDNF | 10% decrease |
| Value decreased per 40Kg ($) | Reliable data not found (RDNF) | | | *15% | *33% | *20.32 | RDNF |
| Coarse varieties status | | | | | | | |
| Volume ( in million tonnes) | 1.6 | 264, 223 | 2005, 703 | 3,557501 | 2553,664 | RDNF | 1.6 |
| AVG Unit Price in US$ | 569.499$^{m}$ | 885 | 511 | 393 | 444 | 70m In July | 920 |
| Average price per tonne (US$) | NF | 400 | 360 | 330 | RDNF | | |
| Annual growth in export (%) | Average 25 | | | | | | 15 |
| Value decreased (%) | RDNF | | 6 | 30 | 14 | | |
| Total rice export status | | | | | | | |
| Volume (million tonnes) | 2.74 | 3.058 | 2.93 | 4.7 | 4.2 against target 4.5 | 3.025 | 3.4 against target 4.0 |
| Value in US$ | 1125829$^{m}$ | 1836.1m | 2.044b | $\Delta$2.26$^{b}$ | 2.5b | 159$^{m}$ | |
| Annual growth in export (%) | Average 25 | | | 57† | continue | Awaited | |
| Value decreased (%) or by Volume | RDNF | 12 | | 31 | continue | Over 15% by Volume | |

**Source: Malhi (2012a); Anonymous (2008); http://www.dawn.com.wpscommentdawn-cotent-librarynewsbusiness; http://www.thenews.com.pkbusiness; m = million; b = Billion; $\Delta$10.82% increase in price value against volume growth to 57%; †market expanded from 76 countries in 2008-09 to 91 countries in the year 2009-10. * indicates value increased by 12% against volume increased by 17% is in case of super basmati fine quality aromatic rice category.**

The decrease in price value has host of concerns including trade policies, bulk production and failure in new technology development to counter the crop lodging and shattering phenomena. When lodging at maturity, basmati rice may be infested by the aflatoxin due to its stay on soil. Considering paddy (the rough or unprocessed rice) and milled rice (the processed or edible rice) as the concern to ascertain grounds for declining price value of our cargo rice, we collected enough number of samples of these products from basmati rice growing in Pakistan and checked physical/optical parameters for DOM (degree of milling), Whiteness, Transparency, FM (foreign matter), UMG (under milled grains), MC (maximum moisture contents), DG (damaged grains), CG (chalky grains), BG (broken grains), CV (contrasting varieties) and shrunken/shrivelled grains, each percent weight by weight of sample.

For rough rice quality testing, moisture contents, green and immature grains, chopped/ damaged grains, foreign matter comprising dust, earth gruel and other non-productive material, total milling recovery and whole or head rice recovery were taken into consideration (Liang et al., 2008; Jongkaewwattana and Sirri, 2004; Jindal and Siebenmorgen, 1994). Addressing these factors will reduce the substantial loss in foreign exchequer for Pakistan.

## Materials and Methods

**Sampling:** Four hundred samples of edible or processed rice and rough or unprocessed rice were collected randomly from various sites located in the historical basmati rice zone of Pakistan (Fig. 1). Three hundred samples of edible or milled rice were taken from factory outlets and hundred samples of rough rice were taken from rough rice markets located in the same rice area according to the method of Davis et al. (1980). Analysis of samples was carried out in the ISO 17025 certified Grain Quality Testing Lab, Food Science and Product Development Institute, Islamabad. Varietals contribution of basmati varieties in sampling is shown Table 3.

**Instrumentation:** Triple Beam Physical balance, Ohuas, USA; Testing Thickness Grader TWSB, 'Satake®'; Testing Rice Grader TRG05, 'Satake®'; Milling Meter MM 1D, 'Satake®'; Sieves of different mesh/sizes (mm) TS-3 and TS-4 set, Fuji- KINZOKU; Electrical paddy cleaner, Testing Winnower PS, OHYA TANZO Engineers, Co. Ltd, Moisture Tester PB 1D2 'Kett'; Standard mills for husking and polishing rice 'Satake®' Co, Pvt. Ltd. were used. All machines are for physical quality testing and are made in Japan.


**Figure I. Map of sampling from rice agro-ecological zone-II of Pakistan**

**Table 3. Varietals contribution of Basmati varieties, their % milling degree, % whiteness, and % transparence in milled rice300 samples**

| Cultivar Name | Varietals (%) contribution | Optical parameters as per MM 1D Satake® reading | | |
|---|---|---|---|---|
| | | Samples % with DOM (6–9g) | Samples % with Whiteness (35–38%) | Samples % with Transparence (1–2%) |
| Super-basmati | 82 | 38 a~~70-90% bran removed | 31a | 29.34ac |
| Shaheen-basmati | 4 | 4b | 38bd | 49b |
| Basmati-385 | 10 | 2c | 44dc | 0 (Max Transparence < 1%) |
| Basmati-2000 | 4 | 4b | 35bd | 27ac |

**Means followed by same litters in the column are not significantly different at P < 0.05 level**

**Rough rice testing:** Rough rice sample was cleaned from straws using electrical rough rice (paddy) cleaner Testing Winnower's, OHYA TANZO Engineers, Co. Ltd. Percent moisture contents (MC) were determined using Moisture Tester PB 1D2 'Kett'. Cleaned samples were dried when needed to 12–14% MC (recommended range for processing) using lab oven at 40$^0$C and digital grain moisture tester. Each sample was weighed, using Triple Beam Physical balance. Fraction of each factor, viz., green and immature grains, chopped/damaged grains, dust, earth gruel and foreign matter was noted manually and physically. Brown rice, total milling recovery, whole/head rice recovery, shrunken or shrived grains and production of husked or partially husked grains was determined by processing 300g of each cleaned rough rice sample using standard mills for husking and polishing rice 'Stake®' Co, Pvt. Ltd. according to the method of Champagne et al. (1997). Rough rice physical quality was evaluated following specification of national standards for rough rice processing described by Anonymous (1993) and Iqbal (1992).

Mean (X) and standard deviation (STD) of all the characteristics was calculated on each 300g rough rice sample weight basis.

**Edible rice testing:** Degree of milling (DOM), whiteness and transparency for edible rice was measured using newly installed commercial milling meter 'Stake®' MM1D. Milling meter was calibrated with white and brown colour plates provided with the metre. Zero of MM1D DOM corresponded to the brown plate and 199 to the white plate. MM1D measurements of whiteness, transparency and DOM were recorded as the average of three replications readings (Siebenmorgen and Sun, 1994). US federal government agency, Grain Inspection Procurement and Stock Services USDA/GIPSA (2012) guideline was applied to fix the sample milling status. According to this subjective visual classification, a given rice sample is evaluated as un-milled, zero milled or brown rice (0% milled or 0.0g of bran removed); under milled (0–3.0g bran removed); lightly or partially milled (3–6g bran removed); reasonably well milled (6–9g bran removed); well milled and extra/over milled or polished rice (9-10g bran removed). The maximum proportion of bran is 10-12g/ 100g of rice. Nakoo (powder), chips and other unwanted material from samples were removed through Testing Thickness Grader with various size sieves. Rice was separated into whole grain (full kernel without any broken part), head rice (kernel that retains the length of $8/10^{th}$ or more of the average length of the unbroken kernel as specified for a particular class of rice) or broken (size below ¾ of the full healthy grain) through Testing Rice Grader. Broken rice was further separated into various categories: ¾ broken, ½ broken, ¼ broken, and small broken using different sieves, USDA/GIPSA (2012). Chalkiness was measured by colour sorter GSK5C, 'Stake's, Japan. Five replications 10g each for every sample was taken to determine foreign matter (dust, earth gruel and others), under milled grains, broken grains, small broken, chips, etc., contrasting varieties of admixture, shrunken/shrivelled grains, using sieves set TS-3 and TS-4 following specification for edible rice trade, USDA/GIPSA (2012). Data was analysed, using percentage and standard deviation values for fraction of each indicator on dry weight basis of edible rice.

## Results

Results of milled rice quality evaluated for physical indicators are reported in Tables 3 and 4. Samples were found to be either excellent or good regarding foreign matter content or contrasting variety admixture. More than 40% samples exhibited milling degree below 90% (bran removal 6-9g). Whiteness was in the range 20-40%, while maximum transparency (2.34%) was found in 5% samples only (Table 3). Under milled grains ratio was higher than acceptable range in 24% of the samples. Regarding moisture contents, 82% of the samples were satisfactory but 18% were marginal. Most samples (81%) contained damaged grains beyond the limit (Table 4). Only 14% of the samples contained head rice contents (excellent) and 44% samples were good, while 24% had broken grains in the marginal range and 18% samples had broken grains a fraction beyond the acceptable limit. All samples contained shrunken and shrivelled grains a fraction beyond acceptable limit. Similarly, regarding the chalky grains fraction, only 38% samples were excellent and 48% of the samples had chalky grains a fraction within range. 7% of the samples were marginal having white chalky spot on grains indicating the opaque area while 12% were beyond acceptable limit (Table 4). Overall, 65% of samples were of superior quality and 35% of samples were below standard criteria. Edible rice quality, specifically, head rice yield (HRY), varied inexplicably from one lot to another and from one cultivar to another cultivar, depending upon the produce processing and the rice cultivar.

Results of rough rice quality evaluated for 100 samples are shown in Table 4. Unlike manually harvested origin paddy, the mechanically obtained paddy had poor quality. Combine machine harvested paddy contained substantial contents of mud gruel, straws, extraneous matter and high proportion of immature, light, chalky grains vulnerable to breakage during milling. Price of 40kg paddy of combined machine origin was 20-30% lower than the manually harvested rough rice. Moisture content of this paddy (31% or even more) was higher than the recommended range (21-24%).

**Table 4. *Milled rice quality parameters evaluated (% ratio± STD) of samples (n = 300) collected from various paddy processing units in Punjab**

| Parameter description | †Acceptable (required) range | samples % excellent | (%) samples within range | (%) samples marginal | (%) samples beyond range |
|---|---|---|---|---|---|
| Whiteness (%) | 35–38 | 40 | 70 | 10 | 10 |
| DOM (%) | 80-90% (6-9g removed | 20 | 70 | 10 | 23 |
| Transparence (%) | 1.5–2.0 | 100 | 0 | 0 | 0 |
| FM | 0.1–0.25 | 100±2.0 | 0 | 0 | 0 |
| UMG | 2.0–2.5 | 80±3.0 | 6±1.0 | 10±2.0 | 14±2.0 |
| Max. MC | 12 | 0 | 83±2.0 | 18±5.0 | 0 |
| DG | 0.5–0.7 | 8±0.8 | 3±0.3 | 8 0.8 | 81±1.0 |
| CG | 3.0–5.0 | 38±1.0 | 43±0.5 | 7±0.1 | 12±0.04 |
| BG | 4.0— 7.0 | 14±2.0 | 44±2.0 | 24±2.0 | 18±0.3 |
| CV | 7.0—10.0 | 83±3.0 | 17±1.0 | 0 | 0 |
| 8Shrunken/ Shrivelled grains | 0.5—0.7 | 0 | 0 | 0 | 100 ± 1.0 |
| LSD (0.05) | | 40.8 | 24.5 | 8.4 | 28.2 |

*Milled rice shall be whole or broken kernels or rice from which hulls and practically all the germs and bran layers have been removed. †USDA Standards; DOM (degree of milling); FM (foreign matter) include all matters other than the rice kernels including "Nakoo" the rice powder; UMG (under milled grains) kernels or pieces of rice having one fourth or more surface covered with husk or bran and/or having one fourth or more surface area covered with red coating; Maximum moisture contents present within the grain; DG (damaged grains) shall include kernels or piece of kernel of rice particularly wholly eaten or bored by insects and / distinctly damaged by water, fungi, or other means; CG (chalky grains) kernel or piece of kernel of rice of which half or more is chalky. Such grains have chalky white appearance and are opaque with the exemption of white inherent spot in the grains of Basamti-385 or IR-6 or else similar; BG (broken grains) of the size below ¾ of the full healthy grain; CV (contrasting varieties) superior or inferior varieties other than the major component of the stock; Shrunken/shrivelled grains are un-hulled or partially hulled or hull only without the kernel inside it or immature and dead kernels or pieces of kernels which are not fully developed and are greenish in colour.

## Discussion

**Edible rice:** Edible rice is food obtained from processing rough rice by optimising various milling parameters. In primary processing, rough rice is changed to raw or brown rice which under goes secondary process of milling, grading and polishing, transforming to head rice, available as edible rice. All samples of milled rice (white rice) were excellent or fine regarding elements of foreign matter or % moisture contents. No sample was without shrunken/shrivelled grains (Table 4). Shrunken/ shrivelled grains are un-hulled or partially hulled or hulled only without the endosperm inside the kernel or an immature kernel. Dead kernels or pieces of kernels are those which are not fully developed and are greenish in colour before milling (Ming and Bergmann, 2005). Previously, presence of such factor could not be excluded (Lu et al., 1995). Currently, this element can be managed due to good agricultural practices. Quality of most samples was not good as they contained an alarming proportion of broken kernel Furthermore, a formidable percentage of chalk and damaged grains were also present (Table 4). Prisana and Linnemann (2008), Rachmat et al. (2006) and Kshirod (1987) have indicated proportion of broken grains and chalky grains as major traits on the basis of which rice is valued at every stage, particularly from production to consumption. Our results are also of similar type. In all markets, physical indicators are almost considered as indicator of consumer acceptability and end-use. These indicators are normally common and include foreign matter, under-milled grains, maximum moisture contents, damaged grains, chalky grains, broken grains, contrasting varieties admixture and shrunken/shrivelled grains. In this respect, rice sold in domestic markets is first graded by varietals groups or classes, and then assessed for physical quality within the class. For example, the fine quality aromatic basmati group are either coarse, IRRI-type group or hybrid group. Then, the increased proportion of broken grains reflects the corresponding chalky grains fraction as has been indicated by Indudhara and Bhattacharya (1982a). The basmati rice may be immature and have cracked kernels, as classified by Ming and Bergmann (2005) and Indudhara and Bhattacharya (1982b). The occurrence of both types of low potentials grains before milling of paddy, as classified by Tashiro and Wardlow (1991), is another example. Chalky grains generally break during milling because starch in these grains is loosely packed and opaque and hence enough broken proportion occurs. A similar ground has also been reported by Correa et al. (2007), Zhang et al. (2005) and Lisle et al. (2000). Contrary to aroma/fragrance, chalk is now a dominating marketing trait. When present correspondingly desperate the consumer. Farmers normally face a decrease in price of 10–25%, for such chalky products (Table 3), while selling rice domestically. Exporters are asked to meet strict criteria for chalk content. Significance price penalties are imposed if the strict criteria is not met (Prisana and Linnemann, 2008; Rachmat et al. 2006). Rice sold in international market is subjected to the criteria specified for each of the six grades USDA/GIPSA (2012). Chalky rice is given a lower grading in the USA (American) markets and the lowest grade fetches up to 25% below the highest grade of rice within a varietals class. The price differential between US grade 1 and 3 is US$35/tonne (for 2 – 6% chalk occurrence in case of medium size grain) and for long size grain (fine type, like basmati); price differential is US$50/tonne for 1-4% chalk. The chalky grains reduce the palatability of cooked products. Thus, the presence of more than 20% chalkiness in rice kernels is not acceptable in the world markets (Cheng et al., 2005). Minimising the chalk would secure the export of Pakistani rice. Potential income will increase the yield and quality of edible rice per 40kg for rough rice processing, possible by as much as 7%.

The presence of chalk in milled rice might be due to high temperature, as has already been reported by various researchers (Counce et al., 2005; Matsue et al., 2002; Tashiro and Wardlow, 1991; Wongpornchai et al., 1991; Masako et al., 1984). Effects of temperature on kernel development are established in different studies. Higher temperatures during the grain filling stage of its development result in decrease in a kernel mass, a decrease in a kernel physical dimensions and an increase in the intensity of chalkiness within a grain or in the proportion of chalky kernels (Tashiro and Wardlow, 1991). On the other hand, lower growth temperatures result in an increase of amylose content in rice cultivars with low amylose content and in a decrease of amylose content in rice cultivars with high and intermediate amylose contents, sometimes changing the cultivars amylose class, depending upon the temperature treatment. Research indicates that during high temperature, grain filling is poor and that tropical germplasm (tropical *japonica* and *indica*) is more susceptible than temperate japonica germplasm (Bhattacharya, 1980). Similar results have been reported during "IRRI", coordinated "DPPC 2006–85 'ACIAR project # CIM-2006–176, on "Developing molecular markers to enable selection against chalk in rice". In Pakistan's rice ecology zone-III, temperature goes up to $50^0$C during rice season. Therefore, to protect the price decrease, temperate rice cultivars should be sought for low chalk (McDonald, 1994), especially as temperature gets warmer due to global climate change Subramanian, 2010).

Similar to physical indicators, a few optical factors, such as, maximum milling degree, whiteness and transparency, have imperative affect on edible rice quality. Higher milling degree makes the grain more white or pearly. Consumers like pearly white or translucent appearance rice (Rachmat et al., 2006). However, under milled, partially milled, shrunken/shrivelled grains, chalkiness admixture of varieties or presence of rice powder/dust reduces the transparency and whiteness of rice. Emergence of such indicator in the edible rice or head rice beyond specific range reduces the chances of selling (USDA/GIPSA, 2012). Regarding the admixture of contrasting varieties (Table 4); there was no sample present in the range beyond or even in the marginal range group. This indicates sample purity for export purpose. On the other hand, absence of inferior or superior variety admixture also implicitly means that only single variety of super basmati is predominantly cultivated in the historically basmati bowl of Pakistan, while other varieties are cultivated in patches (Table 3). Super-basmati is the most popular variety among farmers for the last fifteen years. It is a mega variety and has been cultivated across the border, too. The increased proportion of broken grains may also due to the prevalence dependence on this variety. It has genetic deficiency that its tips break during milling and one cannot get exclusively whole rice during processing. Broken grains fraction cannot be excluded in such circumstances. This aspect can be reduced by replacing this variety with another conforming cultivar or adaptation of new low chalk varieties.

An insight into the Table 2 indicates that price value of our export rice has decreased from average US$1500 or more per tonne during 2007-08 to 825 US$ during the year 2009–10 contrary to market expansion to 109 countries from 76 countries in 2008–09. This is a sheer wastage of this precious commodity at such low rates and loss of foreign earnings also. Further, Pakistan anticipate export around 3.4 million tonne of rice in 2012-13, meaning a decline of over 15% from the targetted 4 million tonne export of rice. Basmati rice export during 2010-11 was 975, 588 million tonne (MT) worth $823.16 million as per details available from the Quality Review Committee (QRC) report. Iran is the second biggest importer with 155,903 MT of basmati imports at an average unit price of $580 per tonne which is $264/MT less than the $844/MT average price of total basmati exports during this year. The average unit price of $581 per MT in the case of Iran is astonishingly low (at $20.32 per 40kg, at Rs. 86 per kg works out to be Rs.1998 per 40 kg), even falling below the domestic market rates of basmati in the country which have remained above Rs.2200/per 40kg even at the lowest rates during the year. Secondly, out of the 108 countries to which basmati rice was exported during the year 2010-11, it was below 100 tonnes to 38 countries, below 1000 tonnes and above 100 tonnes to 29 countries, below 10,000 tonnes and above 1000 tonnes to 26 countries, below 100,000 tonnes and above 10,000 tonnes to 13 countries. Above 100,000 tonnes there were only two countries, UAE being the first with 264,596 tonnes and Iran being the second with 155,903 tonnes. Conclusively above 10,000 tonnes of basmati exports were restricted to just 15 countries. It seems that inferior quality turned exporter to seek non-conventional poor markets for import, unlike the traditional rich western countries and Arabian Gulf nations. On the other hand, Vietnam, a competitor of Pakistan, sells its rice for US$ 664 per tonne in the international market. Vietnam's rice is equal in quality to Pakistan's Mehran-69(IR-6), a coarse group variety which fetches maximum US$ 370 per tonne. Mehran-69's quality could not be improved in the last 40 years yet it contains some taste and is liked by African countries. A similar failure can be previewed in developing new technologies, addressing the lodging, shattering or late maturing phenomena.

During the year 2010-11, Thailand sold its non-basmati rice at US$ 450 per tonne while REAP (Rice Exporting Association of Pakistan) sold the same variety at US$ 300 per tonne. In the year 2008, India sold its basmati (fine quality group variety) at US$ 1500 per tonne while Pakistani basmati fetched only US$ 1300 per tonne in the international market (Rauf, personal communications). From 1$^{st}$July, 2009 to 30$^{th}$ June, 2010 rice export touched 4.6 MT (million tonnes) against 2.93 MT, corresponding previous year. Overall value increased only by 10.82% to US$ 2.26 billion against US$ 2.04 billion during corresponding period in the last year (Hamid Malhi, 2012a**)**. In a nutshell results are bulk export at reduced price value (Table 2).

This is obvious, since exporters want cheap rice from Sheller (old type rice processing units) for selling in the international market to retain a client(s) or to make a new client. Sometimes, processors blend the Basmati variety with long or medium size non basmati variety or so-called basmati variety. As a result, they despatch the basmati consignment at low rates in the competitive market. Consequently, putting pressure on the over all basmati export value. This matter can be controlled through QRC by the standardisation of accepted basmati varieties which do not allow admixture of non-basmati varieties above 10%.

The other aspect of gradual reduced quality rice production and export both can be seen that high quality rice is being replaced by comparatively lesser quality IRRI-Type or even by least quality hybrid seeds, which are mostly of Chinese origin because farmers prefer hybrid category rice due to high yield. The exporters are eager to buy cheap rice to market maximum bulk and subsequently get beneficiary loan from state banks as per government policy. If this continues, 70% of area under rice ecology of fine quality basmati rice will undergo to hybrid or coarse (IRRI) type rice. This is evident from the reduced cultivation of the main basmati variety super basmati by 20-25% in the current year as compared to previous years while its paddy price has been seen 10-15% more. Consequently super basmati export will be quantitatively less by 4.8% putting the foreign earnings in a difficult situation.

**Rough rice:** The quality results of about 80 samples of paddy (rough rice or unprocessed rice) collected from paddy markets and farmers' fields of different origins are shown in Table 5. Unlike manually harvested origin paddy, the mechanically obtained paddy is of poor quality. Our rough rice quality can be described in terms of its physical and mechanical properties including moisture contents as key factor (Kocher et al., 1990). Correa et al. (2007), Zhang et al. (2005) and Bhattacharya (1980) have classified rough rice quality as governed by green/immature grains fraction, chopped/damaged grains, foreign matter comprising dust, earth/mud gruel and other non-productive material. Subsequent imperative product milling recovery is low. Lu et al. (1995) has also adopted similar approach. Maximum number of green grains in the ready harvest panicle is 5 (Kocher et al., 1990). Other researchers, viz., Siebenmorgen et al. (1998), and, Jindal and Siebenmorgen (1994), have also reported that higher moisture contents at harvest affect the economic return. Milling quality head rice yield was low in case of grains thick due to moisture adsorption. Similarly, variations in growth temperature also impart variation in grain quality.

**Table 5. Quality of paddy (rough rice) samples collected from farmer's fields and paddy markets in Punjab, Pakistan**

| Character description | Super-basmati (n = 80) | | |
|---|---|---|---|
| | Wheat combine harvest paddy | Hand reap (with sickle) paddy | Required |
| Moisture contents (%) | 32 | 21 | 18–22 |
| Green and immature grains (%) | 20 | 6.5 | 10 (maximum) |
| Chopped/ damaged grains (%) by weight | 12 | Not detected | Nil (for milling) |
| Dust, earth gruel, and others (%) by weight | 15 | Not detected | Nil (for milling) |
| Production of husked grains (%) | 13 | 0.0 | 5 (maximum) |
| Total milling recovery (%) | 49 | 61.6 | 40 (minimum) |
| Whole/ head rice recovery (%) | 43 | 53 | 40 (minimum) |
| Paddy market price (US$) Nov. 24th 2009; Record basmati production (2 MT) In Sind (Coarse IR-6) Market | per 40Kg | 11.6or 11.6 plus against expected 13-14 $ 5-6 $ | @14.4/kg (official) |
| Harvest rate of combine for Super-basmati ('Naurung' Thana Area), District Narowal | Rs, 2000/ha (about US$= 24) | --------------- | |

Mechanisation of paddy harvesting and threshing is common practice now. Various types of machines are used for this purpose. The paddy obtained through the machine meant for simultaneous harvesting and threshing of the wheat crop and hence name Wheat Combine machine (European brand). When the machine is used for rice crop harvesting, it produces paddy of low quality. Because the machine engulfs a lot of immature, green panicles, crop material other than paddy and extraneous matter gives amorphous moist paddy. Further, rice paddy panicle is branched and canopy curved downwards, unlike the wheat crop panicle. Therefore, rice paddy panicle grains are chopped or damaged during harvesting through this machine. Obviously market bids for such paddy heaps are high in the presence of manually obtained paddy (Table 5). This is fortified by the fact that contrary to 100% increase in the price of every item, Pakistani government had to reduce the price of rough rice (paddy) per 40 kg from Rs. 700 to Rs. 600 for non-basmati and from Rs. 1500 to Rs. 1250 for the basmati paddy – the fine quality rice in the year 2008-09 and further reduced price in the subsequent year, too. Reducing price indicates deterioration in quality, not in volume that drives a nation's market chain. As a result, all stake holders from farmers to exporters could face a situation of making little or no profit from their produce (Rachmat et al. 2006). Such a situation has been documented in Vietnam.

Table 5 indicates clear difference between two different origins of paddy quality that is manually harvested against Combine Machine harvested paddy and was shared with farmers at the spot. In case of combine harvesting, paddy product is of poor quality, due to mud gruel, straws, extraneous matter and high proportion of immature, light, chalky grains which, in turn, contribute to more breakage during milling. Moisture contents in mechanically harvested paddy are higher (31% or even more) than the recommended range (21-24%) and will require longer time to dry which is not economical. Millers told that though super basmati has been the most popular variety among farmers for seventeen years, however, due to inadequate sunshine in the months of November-December, paddy of this late maturing variety (145-150 days) requires additional dryings before milling by April. Alternate drying and wetting imparts fissuring to paddy grains (Cnossen et al., 2003). Earth gruel, straws and other unproductive matter in the paddy heap have the potential to retain, absorb atmospheric humidity, particularly, during low temperature time or night and transfer it to the productive or potential paddy grains, making paddy more moist and thick. Consequently, such paddy type has low hardness and is easily damaged, break during milling, as reported by other researchers (Jongkaewwattana and Sirri, 2004; Siebenmorgen et al., 1998; Jindal and Siebenmorgen, 1994). We noted that Combine Machine sucks, as much as, 19% immature grains and produces 13% de-husked grains. These grains transform into shrivelled and cracked grains, respectively, during paddy drying in mill-yard so deteriorating the paddy quality, which in turn reduces the milling recovery and subsequent whole or head rice yield (Melissa et al., 1998; Lu et al., 1995; Juliano et al., 1993). In addition, the starch molecules in the rice grains are granular in shape with polyhedral structure and are arranged in axial fashion, resulting in virtual susceptibility to the grain chopping at the end or even in the middle during the mechanical harvesting. A considerable amount of chopped grains are present in the combine Machine produced paddy (Table 5). The injured paddy is highly susceptible to the airborne *Aspergillums* attack prevalent in the harvesting season (warm and moist), making the paddy soft, easy to break and initiating mould propagation in the products (Davis et al., 1980). Mills personnel shared that Combine Machine paddy needs extra milling and polishing that ends up with white pearly endosperm but the extra or over-milled rice are poor in nutrients as it is accomplished with more than recommended (5%) aleuronic/bran layer removal (Liang et al., 2008; Lamberts et al., 2007; Kent and Kohlwey, 1999).

Excluding the recently introduced Guard Rice® Paddy Harvester, some of the reasons for low quality of mechanical harvest/thresh paddy are early harvesting and/or the usage of Combine Machines due to labour shortage, shortage of time, uncertainty of weather, shortage of green fodder for cattle, land preparation for coming wheat crop, lodging and shattering of the crop. When lodging at maturity, basmati rice may be infested by the aflatoxin due to its stay on soil with adequate moisture. In Pakistan, very short period is available in which wait for crop perfect maturing and/or Combine Machine availability is applicable. As a result, many management factors integrate to the degradation of quality. Thus Cropping pattern needs change in the perspective of mechanisation, changing climate and water problems.

## Conclusion

Chalk was found as the major physical indicator of reduced quality and occurrence of broken grain fraction in the edible rice. Losses in quality of rough rice were responsible for edible rice of low quality. Use of appropriate paddy harvester and temperate cultivars with good agricultural practices alongwith demarcation of cultivated area into various types of rice groups can mitigate the declining quality of our rice.

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